Guidelines for surgical approaches for minimally invasive plate osteosynthesis in cats

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Abstract: OBJECTIVES: Minimally invasive plate osteosynthesis (MIPO) is one of the most recent fixation techniques that embody the concept of biological osteosynthesis. Several studies evaluating MIPO in dogs have been published in the recent years. However, there are few clinical reports of MIPO in cats and no description of the surgical approaches. The purpose of our study was to describe the safe corridors for plate insertion in cats using the MIPO technique. METHODS: The surgical approaches for the humerus, radius-ulna, femur and tibia were developed after reviewing the described techniques and surgical approaches for MIPO in dogs, while considering any relevant anatomical difference between dogs and cats. Following the MIPO approaches, the limbs were anatomically dissected and the relationship between proximal and distal positions of the implants and neurovascular structures was noted. RESULTS: The surgical approaches developed for the humerus and radius-ulna differed from what had been reported previously, because relevant anatomical differences were found between dogs and cats. Anatomical landmarks for safe plate application were described for all the major long bones in cats. No damage to vital structures following plate insertion was detected in the dissection. CLINICAL SIGNIFICANCE: In this cadaveric study, we evaluated the safety of the surgical approaches for MIPO in cats. By respecting the anatomical landmarks described in this report, damage to the neurovascular structures can be avoided performing the MIPO technique in cats.

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Guidelines for surgical approaches for minimally invasive plate osteosynthesis in cats

Summary

Objectives

Minimally invasive plate osteosynthesis (MIPO) is one of the most recent fixation techniques that embody the concept of biological osteosynthesis. Several studies evaluating MIPO in dogs have been published in the recent years. However, there are few clinical reports of MIPO in cats and no description of the surgical approaches. The purpose of our study was to describe the safe corridors for plate insertion in cats using MIPO technique.

Methods

The surgical approaches for humerus, radius-ulna, femur and tibia were developed after reviewing the described techniques and surgical approaches for MIPO in dogs, while considering any relevant anatomical difference between dogs and cats. Following MIPO approaches the limbs were anatomically dissected and the relationship between proximal and distal positions of the implants and neurovascular structures was noted.

Results

The surgical approaches developed for humerus and radius-ulna differed from what is previously reported, because relevant anatomical differences were found between dogs and cats. Anatomical landmarks for safe plate application were described for all long bones in cats. No damage to vital structures following plate insertion was detected in the dissection.

Clinical Significance

Based on our clinical experience MIPO is a valuable technique in cats. In this cadaveric study, we evaluated the safety of the surgical approaches for MIPO in cats. By respecting

the anatomical landmarks described in this report, damage to the neurovascular structures can be avoided performing MIPO technique in cats.

Introduction

Minimally invasive plate osteosynthesis (MIPO) involves the application of a bone plate without making an open approach to the fracture site (1, 2). Following indirect reduction of the fracture segments, small skin incisions are made remote to the fracture site and an epiperiosteal tunnel is dissected bluntly to connect the incisions (3, 4, 5). The plate is applied as a bridging implant in most cases, and the most proximal and distal screws are inserted through the skin incisions. Additional screws can be introduced through small stab incisions using fluoroscopy to guide insertion (5). Several studies evaluating MIPO in dogs have been published in the recent years, describing the technique and reporting the outcome and complications (2, 4, 5, 6, 7). However, there are few clinical reports of MIPO in cats (8) and no description of the surgical approaches.

Thorough knowledge of the local anatomy is important for performing MIPO safely and effectively. The MIPO surgical approaches are limited and do not allow exposing the typical anatomical landmarks used for open reduction and internal fixation. The surgical approaches for MIPO in dogs have been developed based on the open approaches to each bone segment (5, 9). Considering the anatomical differences between cats and dogs, a description of the safe corridors for plate and screw insertion in cats may offer valuable information for performing MIPO in this species. The purposes of this study were 1) to describe the safe corridors for plate and screw insertion in cats using MIPO technique, with attention to the anatomical differences between cats and dogs; 2) to evaluate safety of these surgical approaches by evaluating the anatomical relationship between neuro-vascular structures and the implants after insertion.

Material and Methods

Prior to establishment of the MIPO approaches in cats a comparative dissection was performed in 3 cats (4-5kg) and 3 dogs (20-25kg) to evaluate the respective limbs for anatomical differences relevant to the MIPO approaches. Anatomical dissection was of great value to review the anatomical differences between cats and dogs, allowing adapting the previously described MIPO approaches to cats. Subsequently 44 limbs of 11 cats euthanized for reasons unrelated to the study, were used to develop the MIPO approaches in cats. Cadavers were used within 24h after euthanasia and were stored at 8° C until the approaches were performed. Each hind limb of each cadaver was used for a MIPO approach of both the tibia and the femur. Similarly, each front limb was used for a MIPO approach of the radius and the ulna. For each cadaver either the left or the right humerus was randomly assigned to medial or lateral MIPO. The approaches described in this report are based on the techniques described in dogs, dissections conducted on cat cadavers and our clinical experience using this technique (5). Briefly, after establishing the proximal and distal windows, an epiperiosteal tunnel was created with either small Metzenbaum scissors (humerus, femur) or a Freer periosteal elevator (radius, ulna, tibia) to connect the two incisions. Subsequently an ALPS 6.5 Plate (radius, ulna, tibia) or an ALPS 8 Plate (humerus, femur) were inserted in the tunnel with the aid of Crile forceps placed at the end of the plate in order to assist in sliding the plate in the epiperiosteal tunnel. Following insertion of the plate, the corresponding open approach was performed. Signs of iatrogenic trauma to the muscles, the periosteum and neurovascular structures and their relationship with the plate with the plate in place were noted.

After establishing the approaches in the initial 44 limbs, 14 additional fresh cadaveric limbs (6 hind limbs, 8 front limbs) were used to perform the complete MIPO techniques with insertion and fixation of the plates with two bicortical locking screws in the proximal and distal fragment. Those limbs were also dissected after placement of the implants and any signs of iatrogenic trauma caused by plate or screw insertion were noted.

Results

Humerus

A cranio-lateral or a medial approach to the humerus can be used for MIPO in cats. Indications for the cranio-lateral approach include proximal and mid-diaphyseal fractures. Indications for the medial approach include mid-diaphyseal and distal fractures with limited distal bone stock and cases where double plating is indicated. The lateral approach combines modifications of the approach to the lateral aspect of the humerus, the humeral condyle and epicondyle (9). The animal is positioned in lateral recumbency. The proximal anatomical landmarks for the cranio-lateral approach are the greater tubercle and the deltoid tuberosity of the humerus. A 1 to 2 cm long incision is created at the cranial border of the greater tubercle. Care is taken to preserve the omobrachial artery and vein. The skin and subcutaneous tissue are retracted and an incision is made through the deep fascia cranial to the omobrachial vessels along the brachiocephalicus muscle. The acromial part of the deltoideus muscle is elevated, allowing exposure to the bone. The lateral epicondyle is used as landmark for the distal insertion incision. The skin incision extends from the lateral epicondyle to

approximately 1 to 2 cm proximally. The skin and subcutaneous tissue are retracted and the deep fascia is incised along the cranial border of the lateral head of the triceps muscle, which is larger compared to the dog (9). Access to the bone is achieved between the origin of the extensor carpi radialis muscle and the brachialis muscle. The origin of the extensor carpi radialis muscle is incised proximally and partially elevated. Damage to the deep and superficial branch of the radial nerve is avoided by 1) creating the tunnel between the two incisions from distal to proximal while visualizing the radial nerve, 2) dissecting underneath the brachialis muscle (Figure 1).
The risk of penetrating the supracondylar foramen and injuring the median nerve and the brachial artery needs to be considered when placing bicortical screws in the distal humerus. Damage to the median nerve and brachial artery were observed in one of 4 limbs for which screws were inserted bicortically in the distal metaphyseal region.

For the medial approach a modification of the medial approach to the humeral shaft and the supracondylar region of the humerus is used (9). The cat is placed in dorsal recumbency with the leg placed in abduction. A proximal 2-3 cm skin incision located approximately 1 cm caudal and 2 cm distal to the palpable cranial border of the greater tubercle is necessary for adequate exposure. Due to the larger amount of soft tissue overlying the bone in the proximal part of the medial humerus, careful retraction of the skin and soft tissue with blunt self-retaining Gelpi retractors was found to be beneficial. The brachiocephalic muscle is palpated cranially and the deep brachial fascia is incised between its caudal border and the superficial pectoral muscle. The brachiocephalicus muscle is retracted cranially. The superficial pectoral muscle is retracted caudo- distally with careful attention to the underlying neurovascular structures. After incising the aponeurosis of the deep pectoral muscle along the shaft of the humerus, the proximal part of the biceps brachii muscle is visualized and retracted cranially (Figure 2). The underlying broad tendon of the inserting teres major muscle is an important landmark for the proximal approach (Figure 2, 4). Dissection should not be continued further distal to the insertion of the tendon of the teres major muscle to avoid damages to the brachial artery and the musculocutaneous nerve immediately distal to the aforementioned point.

The medial epicondyle and the supracondylar ridge are used as anatomical landmarks for the distal window. After performing a 2 cm skin incision along the supracondylar ridge, the deep fascia is incised along the cranial edge of the long head of the triceps muscle. Care is taken to visualize the brachial artery and the median and ulnar nerves before the medial head of the triceps is separated from its short part covering the supracondylar foramen. The short part of the medial head of the triceps brachii (9, 10) muscle is carefully elevated while visualizing the neurovascular structures. If necessary for implant positioning, in order to avoid impingement of the neurovascular structures by the plate, cranial retraction of the brachial artery and the median nerve is possible after freeing these structures from the supracondylar foramen by removing its medial border with a rongeur (Figure 3).

A tunnel is created starting distally and connecting the two incisions. Care should be taken to stay underneath the medial head of the triceps brachii and along the caudal edge of the biceps brachii muscle as the neurovascular structures overlie these muscles. This position was found to be beneficial as the distal plate holes can be positioned caudal to the supracondylar foramen and the medial head of the triceps stays in between the plate and the overlying neurovascular structures (Figure 2). Alternatively, the plate can be positioned cranial to the medial head of the triceps in a true medial position. In the proximal window the tunnel is continued superficial to the tendon of the teres major muscle (Figure 2, 4).

The plate is inserted from distal to proximal in order to not damage the distal neurovascular structures. In addition, the large soft tissue coverage and the thorax can make proximal insertion of the plate more difficult. The plate is twisted to allow placing it caudal to the supracondylar foramen distally and on the medial aspect proximally (Figure 2.)

If the median nerve and brachial artery are not freed from the supracondylar foramen the screw hole positioned over the supracondylar foramen is left empty and screws are placed in the adjacent holes (Figure 2.)

Radius

In contrast to the dog a cranio-lateral approach is advocated in the cat due to the change of the orientation of the cranial surface of the radius directing cranio-laterally in the proximal part and cranio-medially in the distal part (Figure 5). The approach resembles a modification of the lateral approach to the shaft of the radius and a dorsal approach to the carpal joint (9). The indications for this approach include distal metaphyseal and diaphyseal fractures of the radius.

Dorsal recumbency of the cat is recommended. The surgical procedure is carried out with the limb extended caudally. The proximal approach is located in a more lateral position than described for the dog (5). A 1-2 cm skin incision is created in the palpable groove between the common digital extensor muscle and the lateral digital extensor muscle at the level where two most proximal screw holes of the plate will be positioned. Small self-retaining Alm retractors may be used for retraction of the skin and soft tissus. The deep antebrachial fascia is incised between the common digital extensor muscle and the lateral digital extensor muscle. The supinator muscle may be elevated for increased exposure taking care not to damage the deep branch of the radial nerve.

For the distal approach the radio-carpal joint is identified by thorough palpation during flexion and extension. A hypodermic needle may be used for better orientation during the surgical procedure. A 1 to 2 cm cranio-lateral skin incision is created just proximal to the radio-carpal joint. The antebrachial fascia is incised between the tendon of the extensor carpi radialis muscle and the tendon of the common digital extensor muscle. If further exposure is desired the tendon of the abductor pollicis longus muscle may be transected. Alternatively, the antebrachial fascia can be incised between the tendon of the common digital extensor muscle and the tendon of the lateral digital extensor muscle (Figure 6). As described in dogs, it is preferable to create the epiperiosteal tunnel from distal to proximal. Care should be taken to preserve the tendon of the lateral digital extensor muscle to the first phalange as it curves cranio-medially at the level of the radio-carpal joint. Insertion of the plate is generally performed from distal to proximal.

Ulna

A lateral approach is recommended for the ulna. The described approaches to the proximal and distal shaft of the ulna and the styloid process are combined and modified (9). Indications include diaphyseal and distal metaphyseal fractures of the ulna, when associated with comminuted fractures of the radius (11, 12). The animal is positioned as described for the radius. A 1 cm long incision is made on the lateral aspect of the proximal shaft. The deep antebrachial fascia is incised and retracted. The ulnaris lateralis muscle can be carefully elevated at its caudal border and retracted cranial to increase exposure.

The styloid process of the ulna is used as anatomical landmark for the distal window. A 1 cm skin incision is made slightly proximal to this point. After incising the subcutaneous tissue, the antebrachial fascia is incised between the tendons of the ulnaris lateralis muscle and the lateral digital extensor muscle. The tendons are retracted and an epiperiosteal tunnel is created. The tunnel is created in a proximal to distal direction to avoid interference with the styloid process of the ulna during instrument insertion.

Femur

We advocate using a lateral approach to the femur, which combines the lateral approach to the greater trochanter and to the subtrochanteric region of the femur and an approach to the distal femur through a lateral incision (9). Indications for this approach include diaphyseal, proximal and distal metaphyseal fractures. The cat is positioned in lateral recumbency. The greater trochanter is palpated and a 1 cm incision is made at its caudo-distal aspect. The caudofemoralis and biceps femoris muscle is identified and the superficial leaf of the fascia lata is incised along their cranial border. After retraction of the deep fascia lata the underlying vastus lateralis muscle is partially elevated off the proximal part of the femur. Subsequently the vastus lateralis muscle can be retracted cranially by placing a small Hohmann retractor cranial to the femur thereby exposing the lateral aspect of the femur. A distal 1-2 cm incision is made just proximal and caudal to the patella in case of proximal metahphyseal and diaphyseal fractures. For distal metaphyseal fractures the skin incision is extended distally to the level of the tibial tuberosity. After incision of the subcutaneous fascia the biceps femoris muscle is identified and the fascia lata is incised along its cranial border. The intermuscular septum between the vastus lateralis and biceps femoris muscle is incised. The distal femur is exposed by retracting the biceps femoris muscle caudally and the vastus lateralis muscle cranially. The two incisions are connected with an epiperiosteal tunnel (Figure 7).

Tibia

A medial approach is recommended for tibial fractures. The described medial approach to the shaft of the tibia and proximal tibia are combined (9). Diaphyseal and metaphyseal fractures of the tibia are common indications for this approach. The cat is positioned in dorsal recumbency at the end of the operating table allowing adequate abduction of the limb in most cases. Alternatively, the cat can be rotated with the respective leg abducted down on the operating table. The tibial tuberosity is palpated and a 1cm long incision is created midway between the tibial tuberosity and the caudal edge of the proximal tibia. The proximal tibia is exposed after incising the tendons of insertion of the semitendinosus, gracilis and sartorius muscle. A 1 cm skin incision is created approximately 1cm proximal to the medial malleolus for the distal approach. Care is taken to preserve the medial saphenous artery and vein (Figure 8).

Discussion

The objective of this report was to develop safe corridors for application of MIPO in the cat. Anatomical dissection was used to define the anatomical landmarks for plate insertion. After creation of a submuscular, epiperiosteal tunnel the plates were inserted and their position was assessed. In a limited number of cadavers, the plates were secured with screws. The neurovascular structures were dissected to evaluate if any iatrogenic trauma occurred. We found no damage of neurovascular structures was caused by dissection or insertion of the plates, although in one cadaver a screw was placed into the supracondylar foramen entrapping the neurovascular structures. Future clinical studies should evaluate the efficacy and clinical safety of the described techniques in cats.

Establishing specific guidelines for MIPO approaches in cats may be important because of the anatomical differences between dogs and cats. The only complication observed in this study was a screw penetrating the supracondylar foramen in MIPO of the lateral humerus. The supracondylar foramen, unique to the feline humeral anatomy, should therefore be considered when selecting the approach for humeral fractures. Placing bi-cortical screws from the lateral to the medial aspect of the distal humerus is associated with the risk of iatrogenic damage to the brachial artery and median nerve, which pass through the foramen (10). Our study confirms this risk during MIPO, as we observed an iatrogenic injury in this location. To avoid this complication, we advocate a medial approach for managing distal diaphyseal or metaphyseal fractures, which present limited distal bone stock. After freeing the brachial artery and median nerve out of the supracondylar foramen, retraction of these structures is greatly improved and bi-cortical screws can be placed in this location from medial to lateral without the risk of iatrogenic damage. However, the potential influence of opening the supracondylar foramen and displacement of the associated neurovascular bundle on postoperative recovery has not been evaluated yet.

The medial approach to the antebrachium required modifications compared to the dog (5). The comparative dissection revealed that the feline radius shows a more pronounced lateral torsion than the canine radius, requiring a lateral approach for a more direct exposure of the cranial surface of the radius.

For the Ulna we selected a lateral approach because lateral plating is preferred over caudal plating as only limited soft tissue coverage is present on the caudal surface potentially leading to soft tissue complications with a caudal placed bone plate. We chose to report a MIPO approach to the ulna because dual bone fixation in cats is associated with less complications compared to only fixation of the radius (11). Plate fixation of the ulna may be especially indicated in cases of highly comminuted fractures of the antebrachium when strong repair of the ulna is desirable to avoid complications and potential revision surgery. A mechanical study reported higher failure loads of dual plate fixation compared to a single plate combined with an ulnar pin (12). The limited soft tissue coverage of the feline antebrachium should be considered when plating both, radius and ulna because of the risk of soft tissue tension at closure.

Neurovascular injuries are reported in people as a complication of MIPO but not yet in animals (2). The only damage to neurovascular structures during dissection of the cadavers found in this study was a bicortical screw in the distal humerus penetrating the supracondylar foramen. However, our findings should be interpreted cautiously because of the inability to evaluate functional and histological nerve injuries such as neuropraxia, axonotmesis or neurotmesis. We found that the lateral and medial approaches to the humerus carry higher risk because of the specific anatomy and close relationship of the neurovascular structures. Especially when performing a medial MIPO of the humerus it is crucial to respect the reported landmarks and individual anatomical differences. Another limitation is that the approaches were performed on intact bones.

In our experience, MIPO can be safely performed in cats for fixation of humeral, radial, ulnar, femoral, and tibial fractures. However, the approaches described in this manuscript are more challenging in clinical cases due to soft tissue swelling and interference with the fractured bones. In cases where MIPO is unsuccessful in restoring alignment or prevents adequate implant anchorage, conversion to an open approach is mandatory.

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